Activity 2
Mapping the Ambient Magnetic Field

Teacher Instructions

1. Setting the Stage—opening discussion

We mapped the field of a dipole magnet. We achieved a bi-lobed representation of the influence the source magnet would have on a test magnet placed near it. A field is an abstract means of describing how an object affects the space and objects around it. Our maps and the term field are deliberate attempts to describe graphically and verbally the response to a force of a sensitive object placed at a particular location in the space. Our maps show only direction and not magnitude. Recall that we know a magnet is affecting another object by the change of motion induced in the object (moved away from or toward magnet) or by the fact that the object did not fall in a gravitational field when placed against the magnet. Both of these are examples of thinking with Newton's Laws, of course.

Do all objects create fields? Does a chair influence the motion of objects in its vicinity?

Remind students of vectors.

The nature of motion and force is that each requires two elements for a complete description: direction and quantity. That is, motion and force are both intrinsically VECTOR quantities.

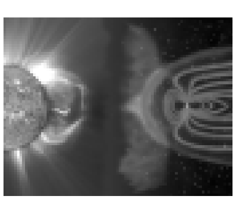
Close discussion by asking students if magnetism demonstrates vector or scalar characteristics. {Vector properties, as it has both strength (magnitude) and direction.}

2. Hand out materials and Student Activity—Mapping the Ambient Magnetic Field. Allow 20 minutes for mapping activity. Students have several questions to answer as part of the activity.
3. Review answers to questions in activity and lead post-activity discussion.
    - **Does the Earth map influence how you interpret the bar magnet map?** {Suggested response: The simple answer is "Yes." The scientific process demands we understand how and to what extent the Earth field affects the mapping of the Bar Magnet field.}
    - **Does the magnetic field of the Earth become more important as we get closer or farther from the dipole magnet?** {Suggested response: The field of the dipole magnet gets weaker with distance. Therefore, the farther the measurement is made from the bar magnet, the larger the influence of the Earth's field on the measurement.}
    - **How far from the bar magnet does the effect of the bar magnet disappear?** {Suggested response: This is a predict-and-check question that reveals a common problem that arises in science. We are measuring the bar magnet field while immersed in the Earth's magnetic field. Thus, one must remove the extra field in order to reveal the true field of the bar magnet. As one gets farther from the source, the magnetic field of the Earth begins to dominate. The key is to determine the field of the Earth, and to subtract it from the measured field to reveal the true field of the bar magnet. The task is frustrated by our not being able to tell if we are in a zero field just from the behavior of the magnetometer: it will always point in some direction! Fortunately, the field of the Earth is very weak (a few gauss) while the field of the bar magnet is relatively strong (10-100 gauss) and thus the Earth's field does not need to be removed until you get out to several lengths of the bar magnet. This question gets back to a fundamental part of magnetism: a dipole field depletes as the inverse cube of the distance between the dipole and the measurement location.
    - **Can the observation be made in such a way that the effect of the Earth's field on the observed bar magnet field is eliminated?** {Suggested response: The students may propose many methods. We suggest that you ask them to carefully develop the hypothesis and logic behind their proposed method. Of special interest is the question, "How will you know you have made a good measurement of the field of just the dipole?" This question opens the student to an opportunity to discuss experi-

mental design and technique. There is no simple way to achieve a measurement of the pure field due to just the dipole. In any technique, the Earth's field must be subtracted from a total measured field OR the experiment must be in a location free from external magnetic fields. While it is possible to create a field that exactly opposes and thus cancels the effect of the Earth's field, it is quite hard to do.}

- **If we are always immersed in the Earth's magnetic field, how can we be sure we are detecting just the magnetic field of the object or magnetic phenomenon we are studying?** {This is the above question rewritten. Simply, we expect to see a certain phenomenon and see something different when a particular new element is added to the system. The change is correlated to the added element. We modify the element (say, by halving and by doubling it) and observe changes in the effect produced.}
- **Use the set of all maps made of the Earth's magnetic field to produce a general map for the entire room. Is the magnetic field in the room entirely due to the Earth?** Explain your answer. {If the extrapolation of the maps leads to a distribution of field lines with a constant direction throughout the room, it is possible that the only contributor to the ambient magnetic field is the Earth. If there are variations in direction, we may presume local sources of magnetic field are perturbing the Earth's field to produce the local ambient field. }
- **How does the sensitivity of the magnetometer effect your interpretation of the maps?** {More sensitive measurements will reveal more small local influences. More sensitive magnetometers may reveal a less uniform ambient field.}

4. Assign "Earth's Magnetic Field and Animals."



Student Activity 2
Mapping the Ambient Magnetic Field

Goal: Obtain a good quality representation of the background magnetic field at location of Activity 1.

Materials:

- Magnetometer
- Large sheet of paper
- Meter stick
- Pencil

Data Collection Procedure:

- Along all edges of the paper, mark points separated by 10 cm and use them to draw a grid on the paper.
- Place and tape paper in the same location as in Activity 1.
- Use the magnetometer to determine the direction of the ambient or background magnetic field at each grid point.
- Record the direction of alignment by drawing a short directed line segment that accurately shows the direction the magnetometer magnet is pointing at that location. The line segment should be centered on the point directly below the center of the magnetometer and should be about an inch long.
- Repeat at each grid intersection.
- Put a legend on the completed map that includes information about the orientation of the map relative to some fixed reference point in the room (a wall clock or a door, for instance).
- Put a title on the map as follows: Ambient Magnetic Field Map, date, and your group identification.

Data Analysis Questions to be completed by you and your partner. Write out your answers in your notebook.

1. Are all the arrows on the Ambient Magnetic Field Map pointing in the same direction? Explain why you think your data is correct or incorrect.
2. Are any of the arrows pointing in the opposite direction, or approximately so, as adjacent arrows? Propose a reason for such variations.
3. Under what conditions can the effect of a magnet change?

Student Activity 2
Earth's Magnetic Field and Animals

Please take a look at some articles (links follow) that look at an intersection of biology and physics: magnetic navigation in animals. The goal here is to understand how your magnetometer is very similar, in some respects, to what is found in some animals. While the way animals detect magnetic fields along with the associated receptor organs (magnetoreceptors or ferro-vesicles) are not well understood, perhaps you can "ferret" out how they work in comparison to your magnetometer. Write a half of a page on the similarities and differences in magnetoreceptors and the compass as developed by the Chinese. Does the consistently seen model of a bit of matter swinging about due to magnetic influence limit the ability of researchers to see when animals are sensing magnetic fields or what they are using the information for?

- A popular news article from ABC News on July 23, 1999, about animals using magnetic navigation. *http://abcnews.go.com/sections/science/DailyNews/magneticnavigation990722.html*
- A story from Science Frontiers Online that begins: *" When magnetite particles were found in organisms from bacteria to bats..."* can be read at *http://www.science-frontiers.com/sf084/sf084b99.htm*
- The abstract of an article in European Biophysics Journal (don't bother with the entire article as you need a subscription to read it.) *http://link.springer.de/link/service/journals/00249/bibs/9028005/90280380.htm*
- A page on magnetic navigation in birds from the National Institutes of Health Resource for Macromolecular modeling and Bioinformatics *http://www.ks.uiuc.edu/Research/magsense/ms.html*
- The page of J Kimball, a biology student, on magnetoreceptors in specific animals. Be sure to follow the link on this page to the micrograph of magnetite particles in a bacterium (at the bottom of the page)! *http://users.rcn.com/jkimball.ma.ultranet/BiologyPages/M/Magnetoreceptors.html*

- A cool picture of the Magnetobacterium bavaricum, a beastie with built-in magnetometers. *http://www.geophysik.uni-muenchen.de/groups/biomag/research/bavaricum.htm*
- An article about the search for magnetoreceptors in the fossil record. *http://www.gps.caltech.edu/users/jkirschvink/magnetofossil.html*
- This site gives a graphical picture of the Earth's magnetic field as measured in Norway. *http://geo.phys.uit.no/realtime.html*